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Microplastic Content in Water and Fish Species in Simanindo Waters, Lake Toba, North Sumatera

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ABSTRACT

With the activities in the waters of Lake Toba will affect the condition of the aquatic environment and also contribute to the presence of microplastics. One of the interesting waste problems in waters to discuss is the presence of microplastics in waters. Microplastics are certainly more than <5 mm in size, there are three processes of microplastic formation, namely biologically, chemically and physically. Microplastics can contaminate fish through fish organs such as gills and digestive tracts. The purpose of this study was to determine the form and abundance of microplastics in the respiratory tract and digestive tract of fish. This study was conducted from November to December 2024. The average abundance in water samples was 21-57 particles / gram while in digestive tract samples it was 37-42 particles /gr dry weight and the last respiratory tract sample was 9 159 particles / gr dry weight. The forms of microplastics found were film-shaped microplastics, fiber microplastics, fragment microplastics and pellet microplastics.

Keywords: Microplastic, Water, Digestive Tract, Respiratory Tract, and Lake Toba.

ABSTRACT

Dengan adanya aktivitas di perairan Danau Toba akan mempengaruhi kondisi lingkungan perairan dan juga berkontribusi terhadap keberadaan mikroplastik. Salah satu permasalahan sampah di perairan yang menarik untuk dibahas adalah keberadaan mikroplastik di perairan. Mikroplastik tentunya berukuran lebih dari <5 mm, terdapat tiga proses terbentuknya mikroplastik yaitu secara biologis, kimiawi dan fisik. Mikroplastik dapat mencemari ikan melalui organ tubuh ikan seperti insang dan saluran pencernaan. Tujuan dari penelitian ini adalah untuk mengetahui bentuk dan kelimpahan mikroplastik pada saluran pernapasan dan saluran pencernaan ikan. Penelitian ini dilakukan pada bulan November sampai dengan Desember 2024. Kelimpahan rata-rata pada sampel perairan sebesar 21-57 partikel/gram sedangkan pada sampel saluran pencernaan sebesar 37-42 partikel/gr berat kering dan terakhir sampel saluran pernapasan sebesar 9 159 partikel/gr berat kering. Bentuk-bentuk mikroplastik yang ditemukan yaitu mikroplastik berbentuk film, mikroplastik fiber, mikroplastik fragment dan mikroplastik pellet.

Kata kunci: Mikroplastik, Air, Saluran Pencernaan, Saluran Pernapasan, dan Danau

1. Introduction

Lake Toba, located in North Sumatra Province, has a surface area of 1,124 km2 (112,400 ha), a lake volume of around 256.2 km3 (256.2 x 109 m3) and a maximum depth of 508 m [1]. Samosir Regency stretches from 2021'38" - 2 049'48" N to 98024'00" - 99001'48" E, with 9 (nine) sub-districts including Sianjur Mulamula, Harian, Sitiotio, Onanrungu, Nainggolan, Palipi, Ronggurnihuta, Pangururan, and Simanindo [2]. Simanindo is a sub-district in Samosir Regency which is an island in the middle of Lake Toba, North Sumatra, Indonesia [3].

Human activities in Simanindo sub-district, Lake Toba, North Sumatra such as industrial activities, household waste, leftover fish farming feed, waste disposal and so on can be factors causing an increase in community waste resulting in microplastic content so that it can cause environmental pollution. Marine debris pollution is a global problem, even in waters far from human activity. Plastic in the aquatic environment will last for a very long time and because it is light, the plastic will be concentrated on the surface of the water [4]. The light nature of plastic causes plastic to tend to float on the surface of the water [5]. Plastic waste in the environment, aquatic and terrestrial, can be exposed to ultraviolet light and undergo degradation and change size. These sizes are divided into 4 levels, namely macroplastics (>25mm), mesoplastics (5-25 mm), microplastics (1-5 mm) and nanoplastics (<1 mm) [6].

The presence of microplastics in the body of an organism can occur either directly or indirectly. The entry of microplastics into the body of an organism directly can occur during the process of searching for food, while indirectly it can come from prey organisms that have been contaminated with microplastics or from the respiration process through the gills. Microplastics in organisms damage organs such as the digestive system. In fish, organs that can be contaminated include the gills and digestive tract.

Gills are organs that have great potential for contamination because these organs function as a place for water to enter and exit for respiration [7], while the digestive tract can also potentially be contaminated because these organs are organs that function for fish to obtain food [8].

2. Materials and Methods Location and time of research

This research was conducted in November to December 2024 which included water sampling, fish samples and measurement of physical and chemical parameters of water in Simanindo sub-district, Lake Toba, North Sumatra, sample analysis in the laboratory and analysis of research data. Fish sample analysis was carried out at the PT Shafera Enviro Laboratory, North Sumatra Province. The research location map can be seen in Figure 1.

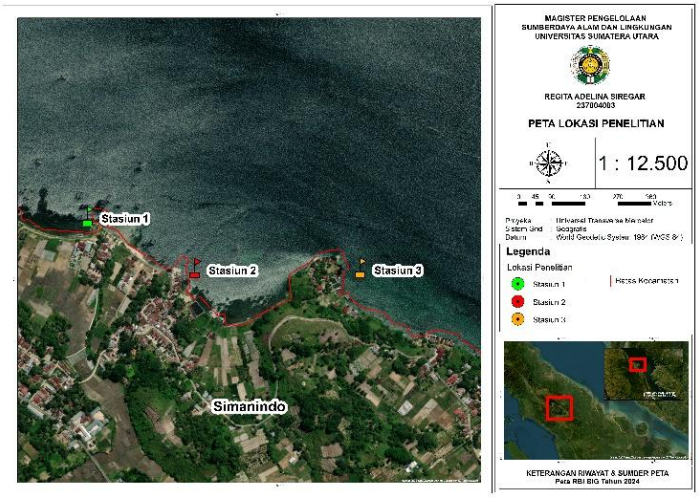

Figure 1. Map of research location

2.1 Data Analysis

2.1.1 Station determination technique in sampling

Determination of stations for sampling is based on environmental characteristics using the "Purposive Sampling" method. According to Lenaini (2021) who stated that purposive sampling is a method of collecting illustrations without being based on random, regions or strata, but rather based on the existence of views that focus on certain goals. In determining the 3 (three) observation stations, the three stations are considered to be able to represent all water locations based on characteristics, namely ports, tourism activities, homestay activities [9].

2.1.2 Sample collection method

Water sampling was carried out using a plankton net (diameter 30 cm and mesh size 30 μm), the plankton net was placed in the water column horizontally and water samples were taken at each station point 2 times and each time the water sample was taken as much as 500ml, the volume of filtered water was 1L which was filtered using a plankton net [10]. The filtered water was put into a labeled sample bottle and taken to the laboratory for analysis.

The fish sampling used in this study was field observation. The survey method was used by providing questions related to the data needed regarding the types of fish landed using fixed gillnet fishing gear at the Sungailiat fishing port. The observation method is a data collection technique where researchers conduct direct observations at the research station to see the activities being carried out [11]. Fish were caught by installing fishing gear nets simultaneously with water sampling. The types of fish used as samples were 3 dominant types of fish and each type was limited to 5 fish and the fish caught were fish that were often consumed, then the fish obtained were stored in a cool box and taken to the laboratory for analysis.

2.1.3 Laboratory analysis

A 200 ml water sample to be analyzed was first given 90 g of saturated NaCl for density separation. Large samples (500-5000 μm) can be separated by filtration with a 500 μm filter size or visual separation, while smaller microplastics (30-500 μm) are separated using a monocular microscope (magnification 4 x 10). This method is applicable to the determination of many common plastics including polyethylene (0.91-0.97 g/ml), polypropylene (0.94 g/ml), polyvinyl chloride (1.4 g/mL), and polystyrene (1.05 g/ml) [12].

The contents of the fish organs in the form of the digestive tract in the form of the respiratory tract (gills) and digestive tract (stomach) were taken from each sample and placed in a 70% alcohol solution for further analysis (Fu et al., 2020; Jantz et al. 2013). Dilution of the contents of the intestines and stomach (digestive tract) of the fish was carried out with a 30% H202 solution. Microplastic particles that were difficult to see with the eye were identified using a monocular microscope (10x10 magnification) [13].

2.1.4 Microplastics abundance analysis

Analysis of microplastic abundance in water was calculated using the formula [12]:

$$K = \frac{n}{v}$$

Description:

K = Abundance of microplastics (particles/m3)

n = Number of microplastic particles

v = Sample volume

Analysis of microplastic abundance in fish can be calculated using the formula [13]:

$$K = \frac{n}{Total\ species\ (fish)}$$

Description:

K: Microplastic abundance (particles/ind).

n: Number of microplastic particles (particles)

3. Result

3.1 Microplastics in the water

The results of the calculation of microplastic content in water samples located at station 1 (Ambarita Port), station 2 (Lake Toba Legend Origin Tourism) and station 3 (Homestay) in Simanindo Waters were found with a number of 2-27 particles/L as seen in Figure 2.

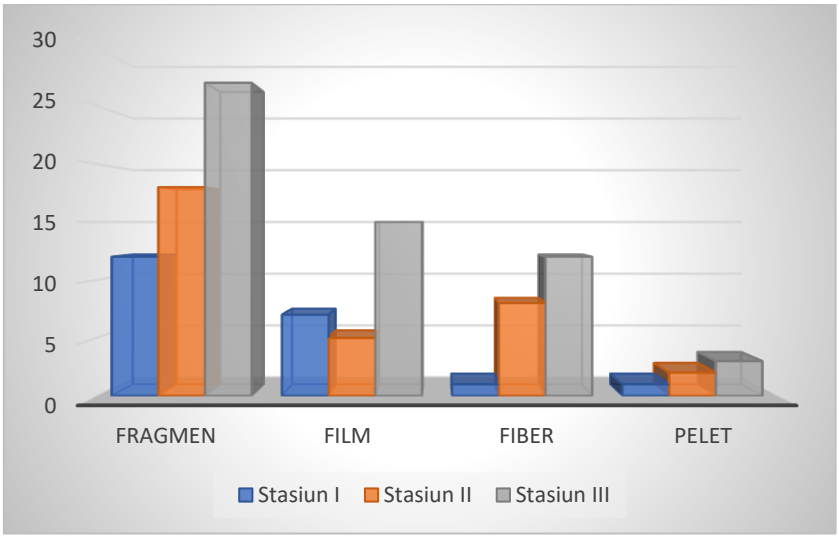

Figure 2. Abundance of Microplastic Types in Water Samples in Simanindo Waters

Based on the research results, the highest average microplastic results in water samples were in the fragment type, namely at Station 3, namely Homestay, with 27 particles/liter, followed by Station 2, namely Lake Toba Legend Origin Tourism with 18 particles/liter and the lowest microplastics were at Station 1, namely Ambarita Port with 12 particles/liter. And the lowest average microplastic results in water samples were in the pellet type, namely at Station 3, namely Homestay, with 3 particles/liter, followed by Station 2, namely Lake Toba Legend Origin Tourism with 2 particles/liter and the lowest microplastics were at Station 1, namely Ambarita Port with 1 particle/liter.

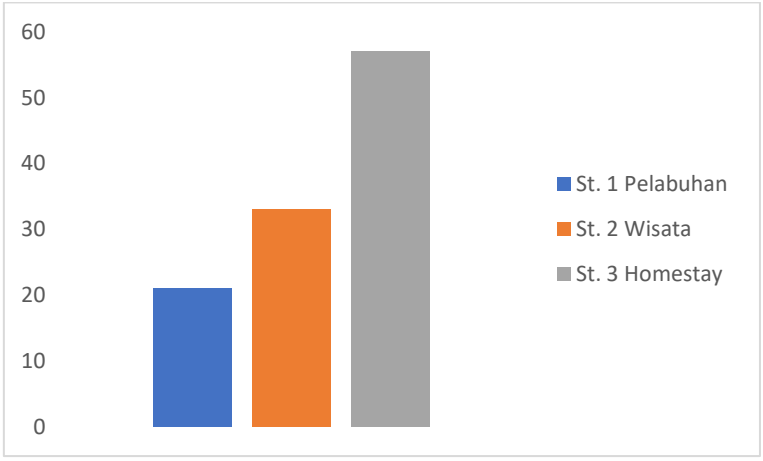

Figure 3. All Abundance of Microplastics at Each Station in the Water Body

Figure 3 above shows that the total abundance in Simanindo waters is different at each station. The results of the analysis of microplastic types as a whole at 3 sampling stations in Simanindo waters show that the highest total abundance of microplastics is at station 3, namely at the homestay, at 57 particles/liter, followed by station 2, namely tourism, at 33 particles/liter and the lowest at station 1, namely the port, at 21 particles/liter.

3.2 Types of fish found in the waters

The total fish samples at 3 stations were 45 fish and 4 species. The results of the abundance of microplastics obtained in each fish species were very diverse. The threat of microplastics being swallowed by biota because their size is quite small makes microplastics easy to be swallowed by biota. In this study, 4 species were found and the scientific names of fish and the distribution of species based on the time of collection are presented in table 1.

Table 1. Distribution of species found at all research stations

No	Latin Name	Local Name
1	*Amphilopus trimaculatus*	Ikan Louhan
2	*Oxyeleotris marmorata*	Ikan Betutu
3	*Amphilopus labiatus*	Ikan Red Devil
4	*Oreochromis niloticus*	Ikan Nila

3.3 Microplastics in the Digestive Tract

The total abundance of microplastics at Station I (Ambarita Port) was the highest in the fragment type at 27 particles/gram dry weight, followed by the film type at 8 particles/gram dry weight and the smallest in the fiber type at 2 particles/gram dry weight. can be seen in Figure 4.

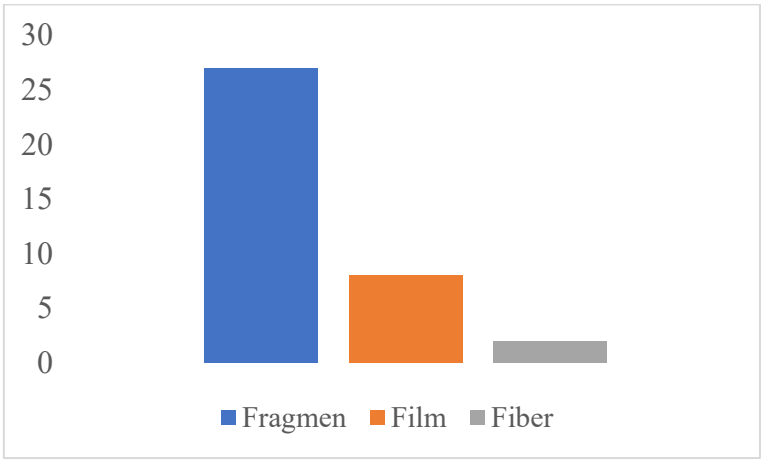

Figure 4. Total Abundance of Microplastics Found in the Fish Digestive Tract of Station I, Ambarita Port

The total abundance of microplastics at Station II (Lake Toba Legend Origin Tourism) was the highest in the fragment type at 28 particles/gram dry weight, followed by the film type at 13 particles/gram dry weight and the smallest in the fiber type at 0 particles/gram dry weight. can be seen in figure 5.

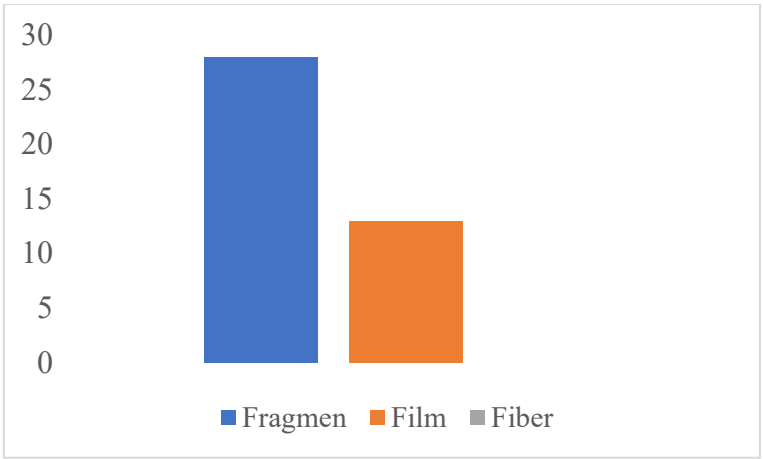

Figure 5. Total Abundance of Microplastics Found in the Fish Digestive Tract of Station II Tourism Origin of the Legend of Lake Toba

The total abundance of microplastics at Station III (Homestay) was the highest in the fragment type of 36 particles/gram dry weight, followed by the film type of 4 particles/gram dry weight and the smallest in the fiber type of 2 particles/gram dry weight. can be seen in Figure 6.

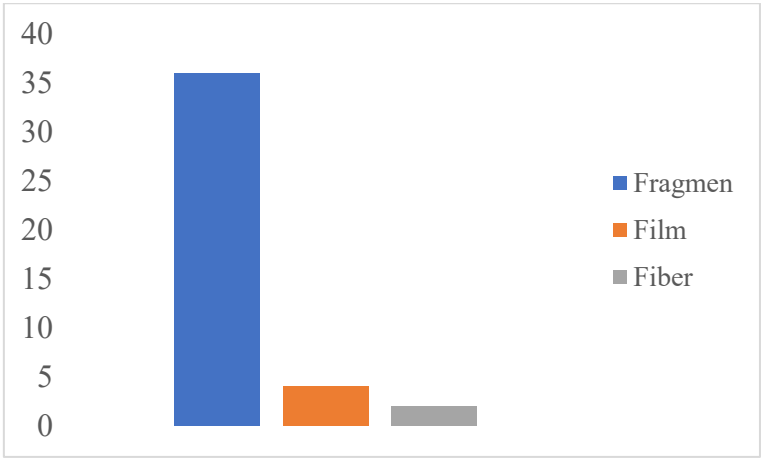

Figure 6. Total Abundance of Microplastics Found in the Digestive Tract of Fish at Station III Homestay

Table 2. Abundance of Digestive Tract Microplastics at Stations 1,2,3

Stasiun	Jenis Sampel	Fragmen	Film	Fiber	Total
1	*Oxyeleotris marmorata* (Ikan Betutu)	11	2	-	13
	Amphilopus trimaculatus (Ikan Louhan)	10	4	1	15
	Amphilopus labiatus (Ikan red devil)	6	2	1	9
	Total	27	8	2	37
2	*Amphilopus labiatus* (Ikan red devil)	10	3	-	13
	Oreochromis niloticus (Ikan Nila)	9	6	-	15
	Amphilopus trimaculatus (Ikan Louhan)	9	4	-	13
	Total	28	13	0	41
3	*Oxyeleotris marmorata* (Ikan Betutu)	14	2	1	17
	Oreochromis niloticus (Ikan Nila)	7	1	1	9
	Amphilopus trimaculatus (Ikan Louhan)	15	1	-	16
	Total	36	4	2	42

3.4 Microplastics in the Respiratory Tract

The total abundance of microplastics at Station I (Ambarita Port) was the highest in the fragment type at 36 particles/gram dry weight, followed by the film type at 15 particles/gram dry weight and the smallest in the fiber type at 2 particles/gram dry weight. can be seen in Figure 7.

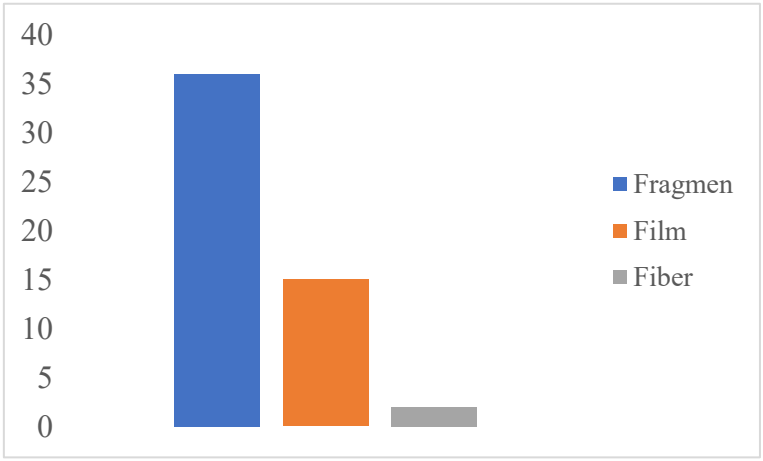

Figure 7. Total Abundance of Microplastics Found in the Fish Respiratory Tract of Station I, Ambarita Port

The total abundance of microplastics at Station II of the Origin of the Legend of Lake Toba Tourism was the highest in the fragment type at 67 particles/gram of dry weight, followed by the film type at 12

particles/gram of dry weight and the smallest in the fiber type at 4 particles/gram of dry weight. Can be seen in figure 8.

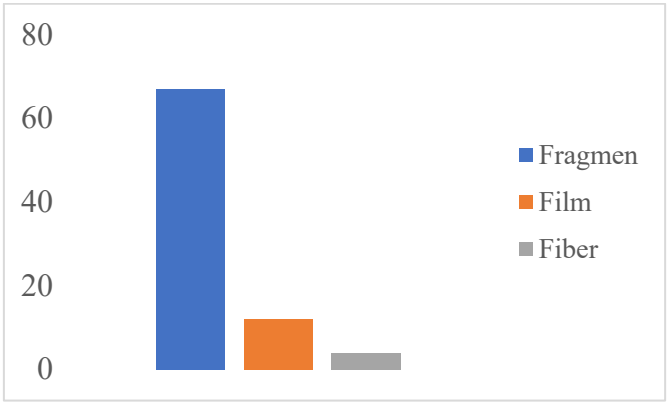

Figure 8. Total Abundance of Microplastics Found in the Respiratory Tract of Station II Tourism Origin of the Legend of Lake Toba

The total abundance of microplastics at Station III Homestay was the highest in the fragment type at 56 particles/gram dry weight, followed by the film type at 14 particles/gram dry weight and the smallest in the fiber type at 3 particles/gram dry weight. can be seen in Figure 9.

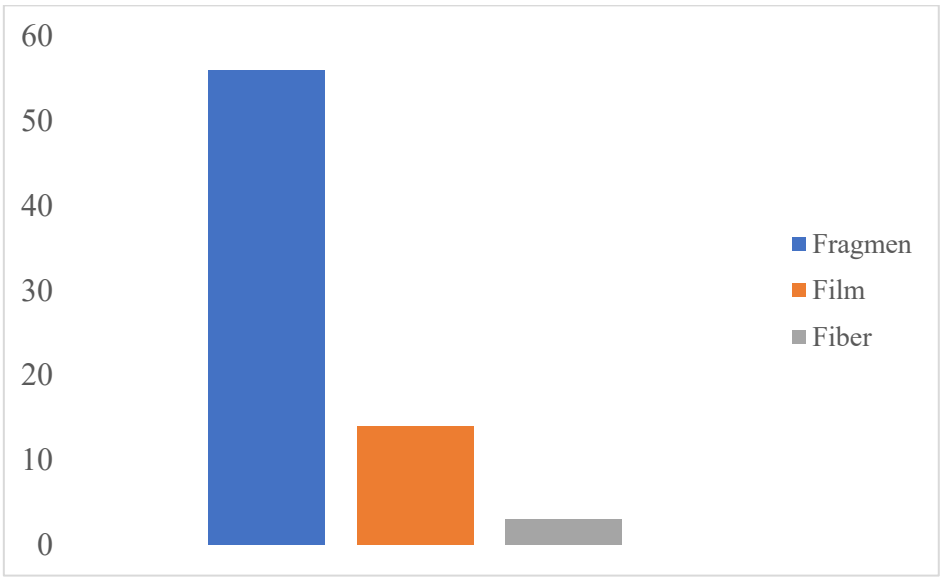

Figure 9. Total Abundance of Microplastics in Channels Respiratory Station III Homestay

Table 3. Abundance of Respiratory Tract Microplastics at Stations 1,2,3

Stasiun	Jenis Sampel	Fragmen	Film	Fiber	Total
1	*Oxyeleotris marmorata* (Ikan Betutu)	9	1	1	11
	Amphilopus trimaculatus (Ikan Louhan)	12	5	-	17
	Amphilopus labiatus (Ikan red devil)	15	9	1	25
	Total	36	15	2	53
2	*Amphilopus labiatus* (Ikan red devil)	19	1	2	13
	Oreochromis niloticus (Ikan Nila)	20	5	-	15
	Amphilopus trimaculatus (Ikan Louhan)	28	6	2	13
	Total	67	12	4	83
3	*Oxyeleotris marmorata* (Ikan Betutu)	13	5	1	19
	Oreochromis niloticus (Ikan Nila)	25	6	-	31
	Amphilopus trimaculatus (Ikan Louhan)	18	3	2	23
	Total	56	14	3	73

3.5 Types and Colors of Microplastics

The types of microplastics that have been identified in water samples, fish planning channel samples and fish respiratory tract samples consist of 4 types of microplastics found at all observation stations (I, II, III) which can be seen in Figure 10.

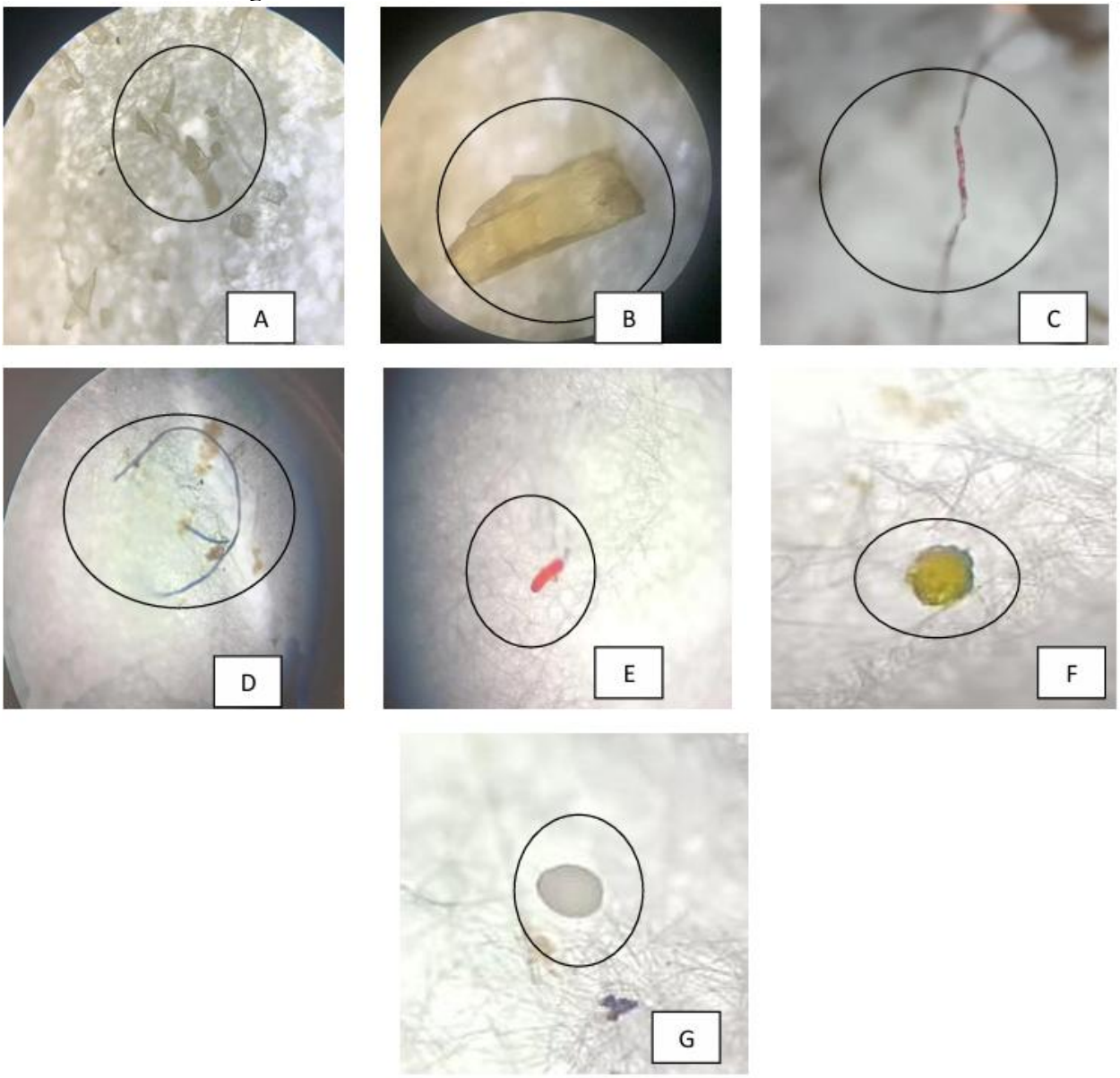

Figure 10. Types of Microplastics in Fish. (A) Transparent Fragments (B) Transparent Films (C) Red Fibers (D) Blue Fibers (E) Red Pellets (F) Yellow Pellets (Source: Research)

4. Discussion

4.1 Microplastics in water bodies

Lake waters have a relatively high summary of microplastics. This is due to anthropogenic activities that occur around the lake. One source of microplastics in the lake is thought to come from domestic activities, such as washing machines [14]. The lake area, precisely in the Simanindo waters, also has other anthropogenic activities that cause the appearance of microplastics in the lake waters, such as agricultural activities, fisheries and household activities.

From the results of this study, the abundance of microplastics is different at each station. The difference in each station is due to the activities of the community and different activities can produce waste and end up in microplastics. This is in accordance with the statement of Haji et al., (2021) which states that wastewater discharge from household activities, industry, and runoff from agricultural activities, settlements or as a place for waste disposal can be a source of microplastics [15].

4.2 Microplastics in Fish

The impact of microplastics on aquatic organisms has become a major concern in environmental research due to their potentially damaging impacts on ecosystems and biological balance. Aquatic organisms are vulnerable to microplastics because of their small particle size and often resembling plankton, which is a food source for many marine organisms. Microplastics can be easily ingested by a variety of organisms, including phytoplankton, zooplankton, fish, and other marine invertebrates [16]. The accumulation of microplastics in organisms can cause digestive disorders, changes in eating behavior, and overall health decline [17].

The impact of microplastics is not limited to individual organisms, but can also spread through the food chain and disrupt the structure and function of the ecosystem as a whole. Organisms that ingest microplastics can transfer the particles to their predators, which can then accumulate in the food web and reach higher concentrations at higher trophic levels [18].

Microplastics that have been released into the aquatic environment pose a threat to ecosystem disruption that will enter the food chain. In fish for consumption, microplastics enter through natural food and contaminated water. Microplastics are found in freshwater fish contaminated with microplastics in the digestive tract and liver [19]. Digestive, growth, and metabolic disorders, while in humans it will cause digestive disorders [20].

4.3 Microplastics in the Digestive Tract

Microplastics that enter the fish's body, one of which is through the mouth to the stomach or intestines of the fish. This is in accordance with Aryani et al., (2022) who stated that microplastics can enter the digestive tract originating from fish food through the mouth and enter the digestive tract and then accumulate in the fish's body [21].

Microplastics obtained from the research results found in the digestive tract of fish come from food waste that is thrown into the water or food waste. This is in accordance with the statement of which states that microplastics found in the digestive tract of fish can come from water, either from food or the food chain (biomagnification) [7]. The shape and size of microplastics that are similar to phytoplankton and zooplankton allow fish to accidentally swallow microplastics.

Microplastics that enter the fish digestive system can also cause negative impacts, namely disrupting fish digestion, such as clogging of its food filter, and its intestines containing microplastics. This is in accordance with the statement from Pramita et al., (2020) which states that fish that accidentally swallow microplastics will accumulate in the digestive tract which has the potential to injure and block its digestive tract and The toxic polymer compounds in microplastics will disrupt the body's physiology [22].

4.4 Microplastics in the Respiratory Tract

The samples taken for research materials to be tested for microplastics are gills. Gills are the respiratory organs of fish that are in direct contact with their environment. This is in accordance with the statement of Lukmini et al., (2024) which states that gills are the respiratory organs of fish. Gills are the first organs to be exposed to toxic substances in the waters due to direct contact with water during the respiration process [23].

Gills can be contaminated with microplastics because they function to filter seawater to get oxygen, which can trap microplastics in the waters in the gills. The digestive tract can be contaminated with microplastics through the food chain. Microplastics found in the gill tract and do not come out with the feces so that they accumulate in the digestive tract and disrupt the digestive process until death. This is in accordance with the statement of Janz et al., (2013) which states that the difference in abundance in the gills and digestive tract found can be due to the different functions of the gills and digestive tract [24].

4.5 Types and Colors of Microplastics

From the research results, the color of microplastics is red, blue, yellow and transparent. The color obtained from microplastics comes from human activities, microplastics also come from waste that is dumped into the waters. This is in accordance with the statement of Seftianingrum et al., (2023) which states that red and blue are the result of human activities, and can be degraded by sunlight. The yellow color is thought to come from plastic bags, mica paper, book covers, plastic straws, and other plastic waste that does not have color density or has undergone ultraviolet light degradation. White is the least color found in this study, and can come from pieces of cork used as a place to store fish or factory waste.

Fragments are a type of microplastic caused by land-based waste carried by currents and entering water areas. So that in water locations there is a lot of floating waste and has even been deposited in the ground.

This type of fragment microplastic has a shape like flakes or is irregular (Dewi et al., 2015). Generally comes from bottles, plastic bags, or fairly thick plastic containers [16]. This type of fragment microplastic has varying densities so that it can make this type of microplastic float in water and also sink. Therefore, this type of fragment microplastic can contaminate fish that move freely or live on the bottom of the water [25].

Film-type microplastics can be influenced by the amount of plastic that is exposed to the fragmentation process or the process of breaking down plastic into smaller pieces, this is in accordance with Imanuel et al., (2022) which states that the film form is a microplastic resulting from the degradation of thin plastic waste such as plastic bags, so that microplastics with this form have a low density which makes it easy to float and be in the water column. This type of film has a low density. This is in accordance with the statement of Yogi et al., (2024) which states that film-type microplastics generally come from plastic bags and packaging and have a lower density than other types of microplastics so that they are easier to transport. This type of film microplastic has an irregular shape. This is in accordance with Yudhantari et al., (2019) which states that film-type microplastics have an irregular shape, are thin and more flexible when compared to fragments. The film is also transparent. The film form looks transparent and thin like a sheet of plastic. Film microplastics have characteristics that are generally transparent, thin and generally come from the remains of plastic packaging or plastic bags [16].

Microplastic fibers come from boat ropes that are attached to tidal areas that experience friction and then break down into very small plastic particles in the waters. This is in accordance with Tuhumury and Ritonga., (2020) who stated that microplastic fibers come from synthetic fabrics that can be released due to washing clothes, fishing nets, industrial raw materials, household appliances, plastic bags that are designed to degrade in the environment, or due to the weathering of plastic products. This is in accordance with the sampling location which is very close to residential areas.These microplastic fibers are related to fishermen's fishing gear, fishermen's fishing gear such as fishing nets, fishing gear has an impact on microplastics. This is in accordance with the statement of Fadhilah et al., (2023) who stated that fiber can be associated with anthropogenic activities, such as fishing activities (fishing gear), fiber is also related to fishing activities because most local fishermen use plastic fishing nets.

The microplastic pellets obtained were small, round like circles. This is in accordance with the statement of Laksono et al., (2021) which stated that the pellets were round, came from plastic factory activities, cleaning and beauty products, resin powder, and plastic production bait. This type of pellet microplastic is a primary microplastic. This is in accordance with the statement of
Riska et al., (2022) which stated that pellets are classified as primary microplastics. The microplastics obtained were red and yellow. This is in accordance with Adila and Windusari., (2024) who stated that pellets with microplastic colors are brown, red, and green.

Based on the Ministry of Health, BPOM, and FAO - WHO have not yet regulated the safe limit of microplastics in food (Litbangkes, 2019). According to Widianarko and Hantoro (2018), to prevent microplastic contamination in seafood consumed, a reference or stipulation by the government is needed regarding the action level (AL) value to see the levels of microplastics found in seafood, whether within normal limits or exceeding the limit. Values that exceed the threshold can be taken by withdrawing from the market or destroying them.

5. Conclusion

From the research results, the form of microplastics in water samples, digestive tract samples and respiratory tracts in fish are microplastics in the form of films, microplastic fibers, microplastic fragments and microplastic pellets. The results of the study on its abundance in water samples were 21-57 particles / gram while in digestive tract samples it was 37-42 particles / gr dry weight and the last respiratory tract sample was 9 159 particles / gr dry weight.

References

[1] Silaban, W and M. V. Silalahi. 2021. Analysis of Water Quality in Lake Toba Waters, Pangururan District, Samosir Regency. Journal of Science and Technology. 10 (2): 299-307. ISSN: 2303-3142.

[2] Aziz, F., Sahid and N. P. Yanto. 2023. Analysis of Shoreline Changes using the Digital Shoreline Analysis System (DSAS) for Tourism Development in Samosir Regency. Journal of Geography Education. 10 (1): 153-166.

[3] Irawan, D. S., D. A. P. Sarly and R. A. A. Putriahalya. 2021 Study of The Carrying Capacity of The Environment Case Study: The Simanindo Area, Samosir Regency, North Sumatra. Agro Bali: Journal of Agriculture. 4 (1): 72-86. ISSN 2655-8534.

[4] Aranxa, V., I. Prihatiningsih., A. Haryati and W. A. E. Putri. 2024. Analysis of Composition and Distribution of Marine Debris (Macro and Meso) on Cemoro Sewu Beach, Pemalang Regency. Maiyah Journal. 3 (2): 107-117. ISSN 2963-4091.
[5] Tuahatu, J. W and N. C. Tuhumury. 2022. Marine Debris Stranded on the Coast of Hative Besar Beach during the Transition Season. Trito Journal. 18 (1): 47-54. ISSN 2656-2758.
[6] Iwasaki, S., A. Isobea., S. Kakob., K. Uchidac and T. Tokaic. 2017. Fate of microplastics and mesoplastics carried by surface currents and wind waves: A numerical model approach in the Sea of Japan. Marine Pollution Bulletin.
[7] Yona D,, M. D. Maharani., M .R. Cordova., Y. Elvania and I. W. E. Dharmawan. 2020. Microplastic Analysis in Gills and Digestive Tract of Reef Fish in Three Small and Outer Islands of Papua, Indonesia: Initial Study. Journal of Tropical Marine Science and Technology. 12(2):497–507. ISSN : 2087-9423.
[8] Yona, D., B. A. Mahendra., M. A. Z. Fuad., A. Sartimbul., S. H. J. Sari. 2022. Abundance of Microplastics in Gills and Digestive Tract of Lontok Fish Ophiocara porocephala Valenciennes, 1837 (Chordata: Actinopterygii) in Dubibir Mangrove Ecosystem, Situbondo. Journal of Tropical Marine. 25 (1) : 39-47. ISSN : 2528-3111.
[9] Lenaini, I. 2021. Purposive Sampling and Snowball Sampling Techniques. Journal of History Education Studies, Research & Development. 6 (1) : 33 39. ISSN : 2549-7332.
[10] Riduwan. (2004). Research Methods. Jakarta : Rineka Cipta.
[11] Yona, D., M. F. Zahron., M. A. Z. Fuad., Y. P. Pranato., and L. I. Harliyan. 2021. Microplastics in Waters Types of Sampling Methods and Laboratory Analysis. Book. Ub Press.
[12] Masura, J., Baker, J., Foster, G., Arthur, C., Herring, C. 2015. Laboratory Methods For the Microplastics in the Marine Debris. National Oceanic and Atmospheric Administration (NOAA), USA.
[13] Boerger, C. M., Lattin, G. L., Moore, S. L., Moore, C. J. 2010. Plastic Ingestion by Planktivorous Fishes in the North Pacific Central Gyre. Marine Pollution Bulletin. 60: 2275-2278. Doi: 10.1016/j.marpolbul.2010.08.007
[14] Permatasari, D. R and A. D. Radityaningrum. 2020. Study of the Presence of Microplastics in Water Areas: A Review. National Seminar on Applied Science and Technology. 8 (2) : 499-506. ISSN :2686-0023.
[15] Haji, A. T. S., B. Rahadi and N. T. Firdausi. 2021. Analysis of Microplastic Abundance in Surface Water in the Metro River, Malang. Journal of Natural Resources and Environment. 8 (2) : 74-84.
[16] Cole, M., P. Lindeque., C. Halsband., and Galloway, T.S. 2011. Microplastics as Contaminants in the Marine Environment: A review. Marine Pollution Bulletin. 62 (12) : 2588-2597.
[17] Wright, S. L., R. C. Thompson., and Galloway, T.S. 2013. The physical impacts of microplastics on marine organisms: A review. Environmental Pollution, 17 (8) : 483-492.
[18] Amanu, A. A., A. P. Zahrani., F. A. Ristaatin., A. R. Ardillah., and D. O. Radianto. 2024. The Effects of Microplastic Waste on Organisms and Handling Efforts. Manufacturing: Publication of the Industrial Engineering Sub-Group. 2 (2) : 12 – 24. ISSN: 3031-3996.
[19] Galafassi, S., C. Campanale., C. Massarelli., V. E. Uricchio and P. Volta. 2021. Do Freshwater Fish Eat Microplastics? A Review with A Focus on Effects on Fish Health and Predictive Traits of MPs Ingestion. Water. 13 (1) : 1-20.
[20] Sulistyo, E. N., E. Rahmawati., R. A. Putri., N. Arya dan Y. A. Eryan. 2020. Identification of the Existence and Type of Microplastic in Code River Fish, Special Region of Yogyakarta. EKSAKTA journal. 1(1) : 85 – 91.
[21] Aryani, D., A. N. Hasanah., F. A. Radityani., D. F. E. Nuryadin., and L. I. Azkia. 2022. Characteristics of microplastics in mackerel (Decapterus ruselli) and tilapia (Oreochromis niloticus) at Rau Market, Serang City. Journal of Aquatic Resources and Fisheries Management. 4 (1) : 1-7.
[22] Pramita, A., A. Ridlo., and C. A. Suryono. 2020. Microplastics in Sediments on Kartini Beach, Jepara Regency, Central Java. Journal of Marine Research. 9(3) : 326–332.
[23] Lukmini, A., S. J. Juanda., S. R. Nuban., and M. F. Panuntun. 2024. Histopathological Description of the Gills of Tiger Grouper (Epinephelus fuscogutattus) as a Bioindicator of Telu Waters
[24] Jantz, L. A., Morishige, C. L., Bruland, G. L., Lepczyk, C. A. 2013. Ingestion of Plastic Marine Debris by Longnose Lancetfish (Alepisaurus ferox) in the North Pacific Ocean. Marine Pollution Bulletin. 69:97-104. Doi: 10.1016/j.marpolbul.2013.01.019.
[25] Fu, Z., Chen, G., Wang, W., Wang, J. 2020. Microplastic Pollution Research Methodologies, Abundance, Characteristics and Risk Assessments for Aquatic Biota in China. Environmental Pollution. 266: 115098. Doi: 10.1016/j.envpol.2020.115098.